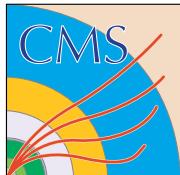


10th International Conference on Calorimetry In High Energy Physics

Jet Energy Reconstruction with the CMS detector

**Shuichi Kunori
U. of Maryland
27-March-2002**

(for the CMS collaboration)



Outline of talk

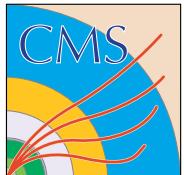
Calorimeter response to single pion

Jet energy corrections
simple correction with mapping
using tracks

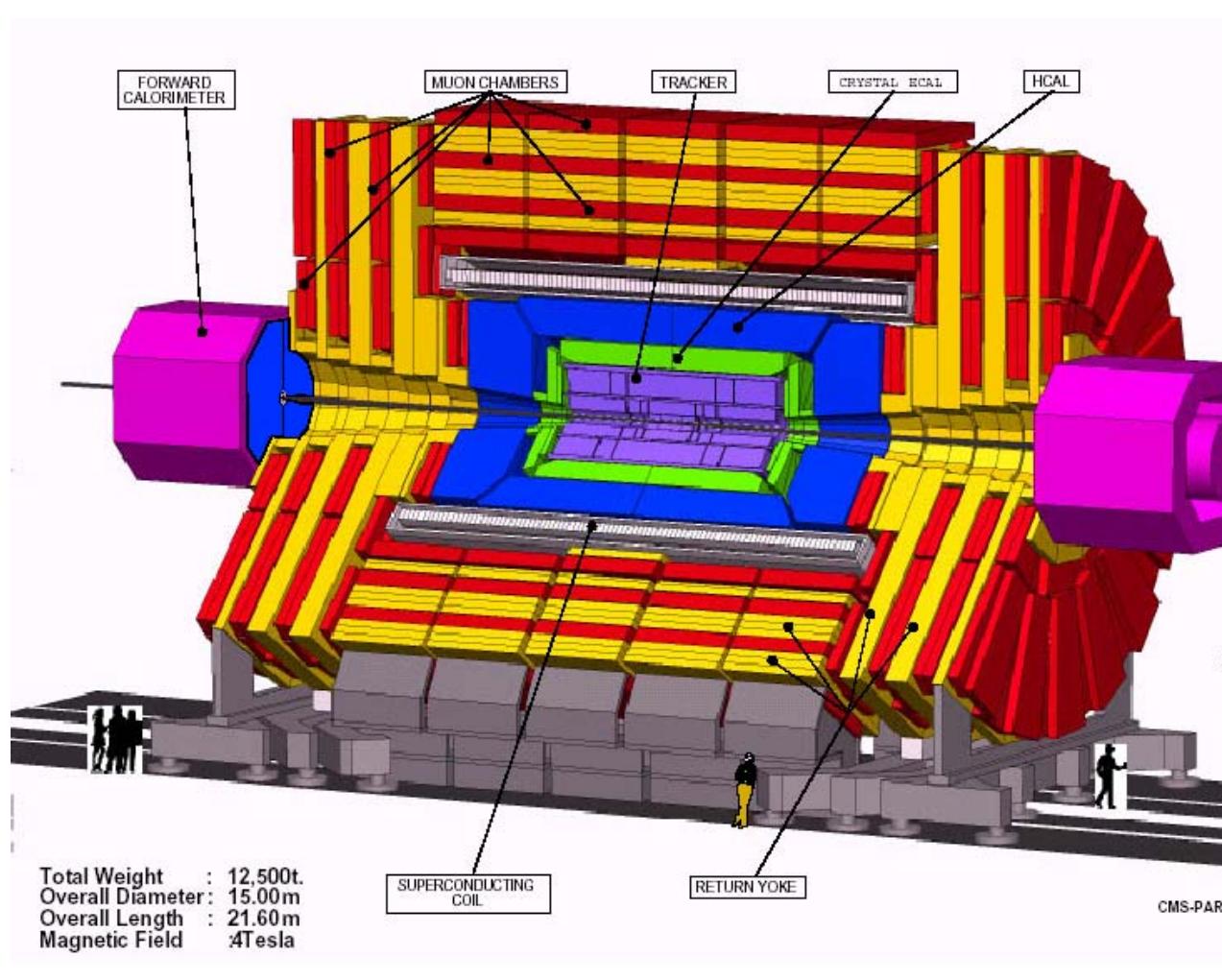
Extensions to MET (missing E_T)

Conclusions

Many Thanks to my CMS colleagues, especially
**S.Abdullin, S.Arcelli, V.Drollinger, S.Eno, D.Green, O.Kodolova
A.Krokhutine, A.Nikitenko, A.Oulianov, I.Vardanyan**



CMS Detector



Tracker
All silicon
 $|\eta| < 2.4$

ECAL
PbWO₄ crystals
 $e/h \sim 1.60$
 $|\eta| < 3.0$

HCAL (barrel/endcap)
Scint-tile & brass
sampling
 $e/h \sim 1.39$
 $|\eta| < 3.0$

– 4 Tesla field –

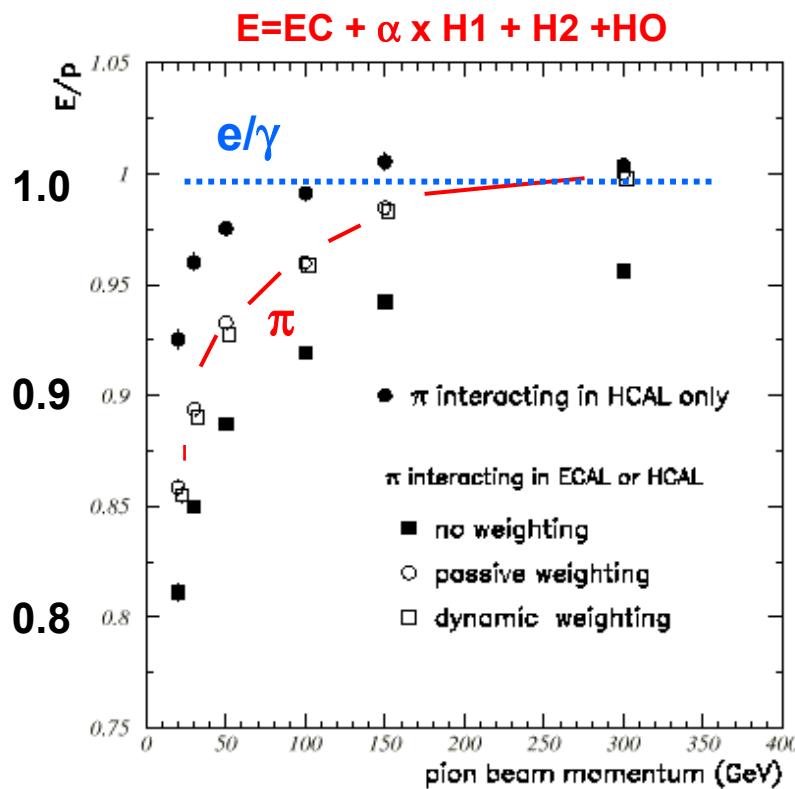
HCAL (fwd)
Quartz-fiber & iron
 $3.0 < |\eta| < 5.0$



Pion Response: Linearity

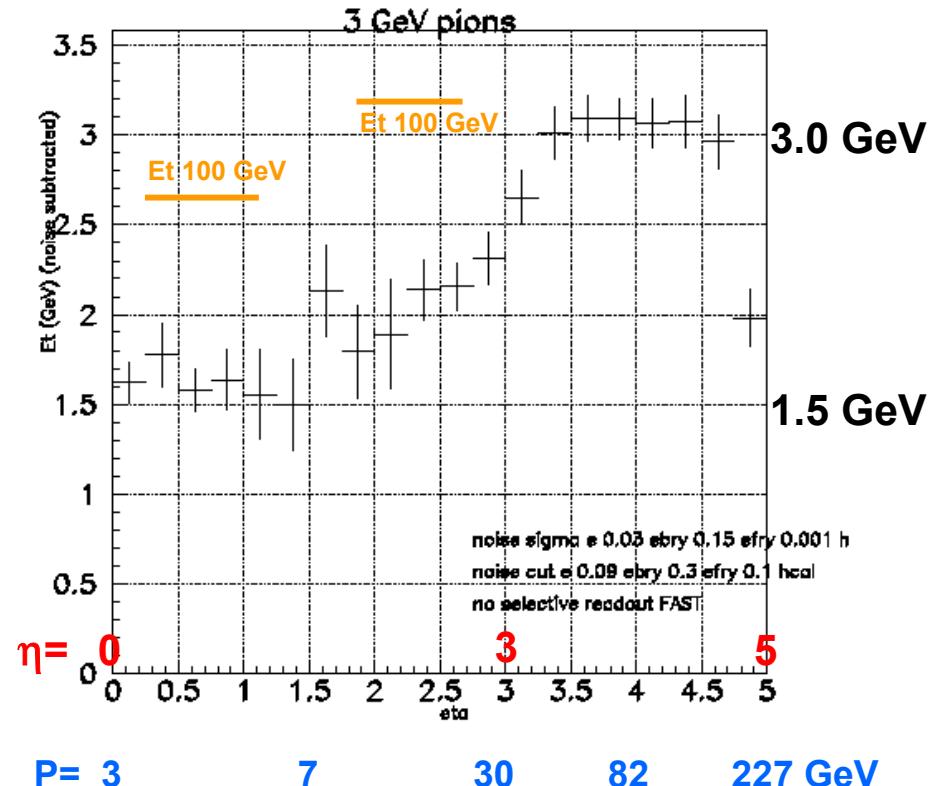
ECAHL+HCAL: Non compensating calorimeter

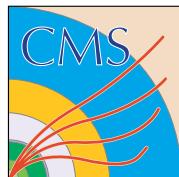
96'H2 Teast Beam Data



CMS Simulation

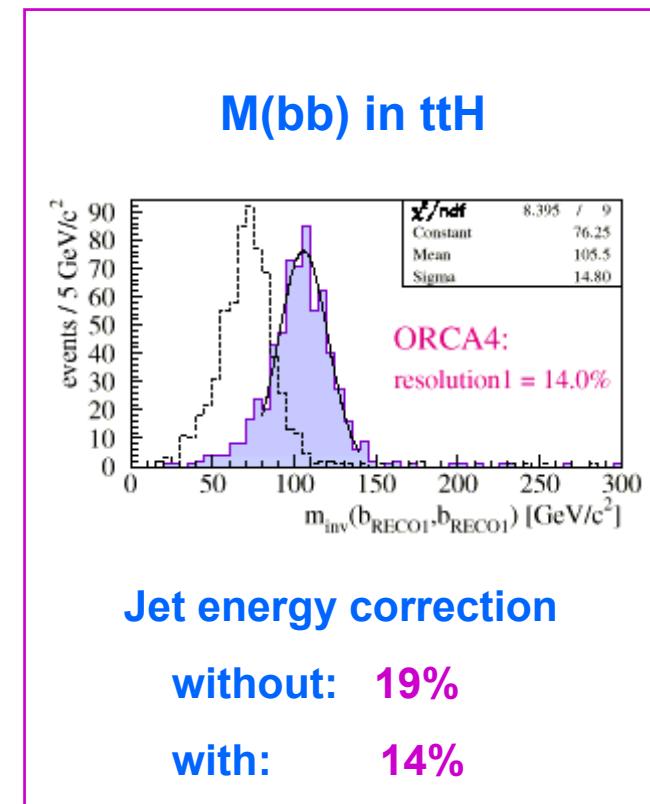
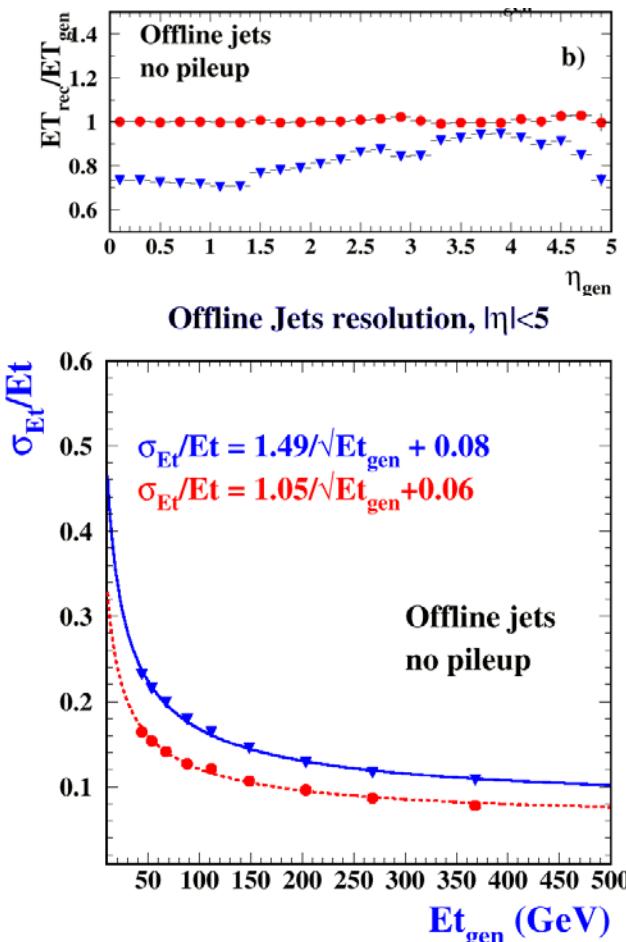
$P_T=3 \text{ GeV}$ pion in $0 < |\eta| < 5$



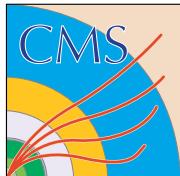


Simple Jet Energy Correction (#1)

Map of response in E_T - η : $E_T(\text{corr}) = a + b \times E_T(\text{raw}) + c \times E_T(\text{raw})^2$
a,b,c depends on E_T and η



→ Level 1 trigger, HLT trigger, offline



Jet Energy Correction

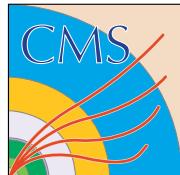
Jet Energy Correction

Correction for detector effects

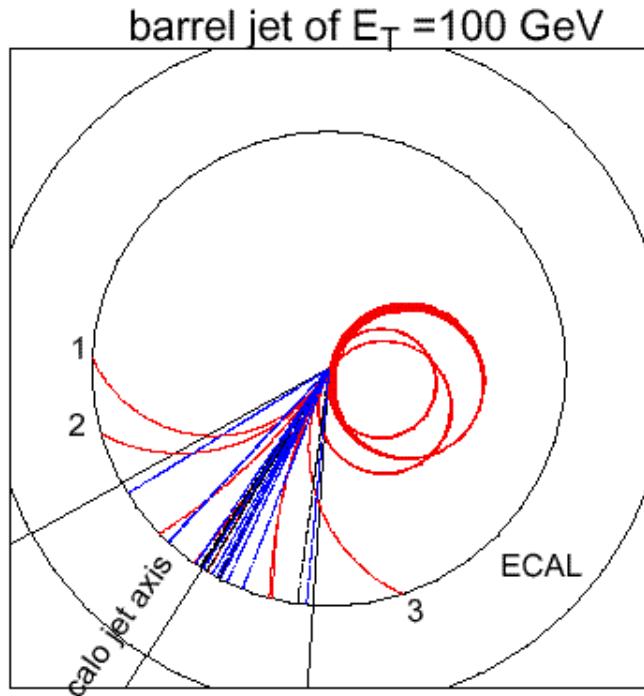
e.g. Calorimeter jet (cone R<0.5) → Particle level jet (cone R<0.5)
(Not for physics effects, e.g. final state radiation etc.)

Algorithms:

- **Jet based**
 - 1) $E = a \times (EC + HC)$, a depends on jet(E_T, η)
baseline: implemented in both trigger & offline.
 - 2) $E = a \times EC + b \times HC$, a, b depend on jet(E_T, η)
Note: no longitudinal segmentation in ECAL (1.1λ) and HCAL
- **Cluster based**
 - 3) $E = em + had$ (using calo only)
Calib. coefficients to em-cluster and had-cluster, separately.
- **Use of reconstructed tracks**
 - 4) $E = E_0 + (\text{Tracks swept away by } 4T \text{ field})$
 - 5) $E = EC(e/\gamma) + (EC+HC)(\text{neutral.h}) + \text{Tracks}(\text{charged.h})$



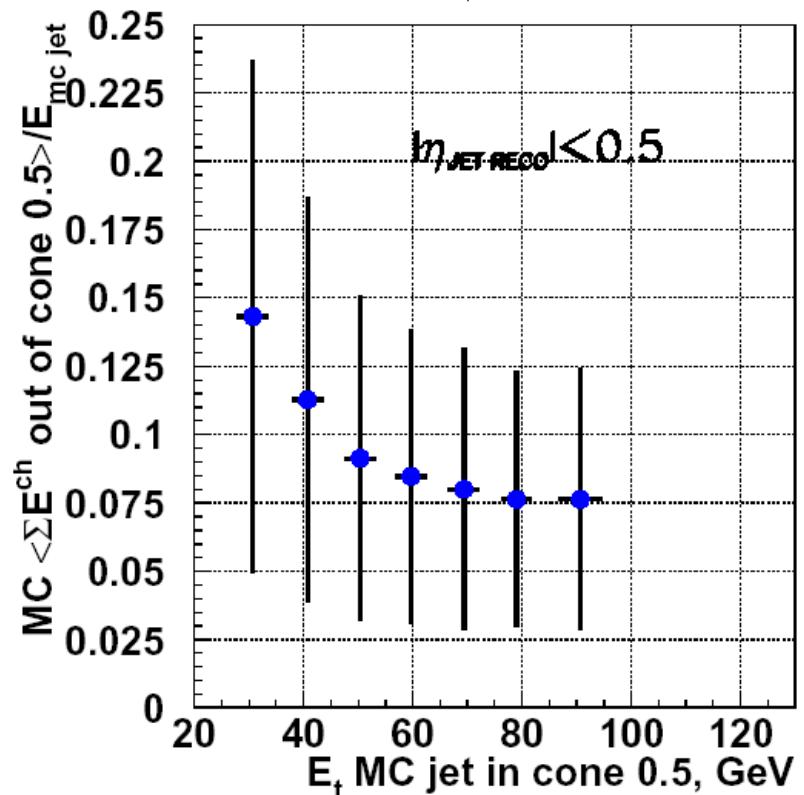
Effect of 4 Tesla Filed

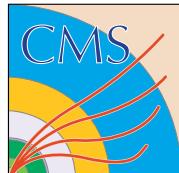


Radius of ECAL front ~ 1.3 meters

Charged particles $P_T < 0.8$ GeV
→ Looper in barrel.

Fraction of energy escape
from a jet cone ($R=0.5$)
in 4T field.

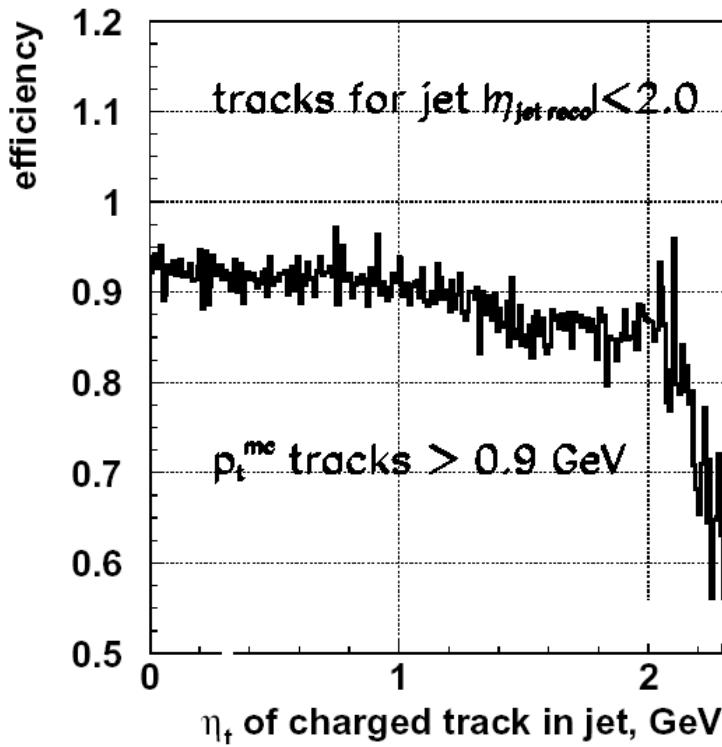




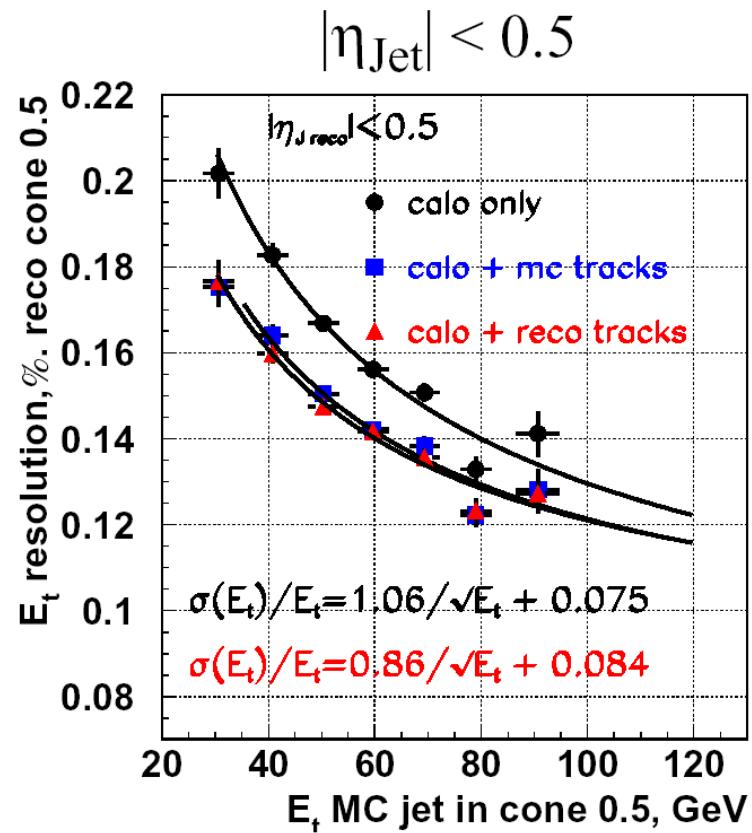
Correction to B-field effect (#4)

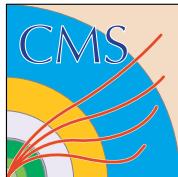
Add energy of charged tracks swept away from jet cone ($R=0.5$) by 4T field.

Track reconstruction efficiency by ORCA (CMS reconstruction program)



Improvement of resolution





Correction using Tracks (#5) "energy flow"

For each track inside jet cone:

Form a cluster around track: 3x3 crystals + 3x3 HCAL

in $\eta x \phi$: $(0.017 \times 3)^2 + (0.087 \times 3)^2$

Track – Cluster match: $-\sigma < E_{\text{track}} - E_{\text{cluster}} < 2\sigma$

where $\sigma/E = 100\%/\sqrt{E} + 5\%$,

if matching is-

YES: $\Delta E(\text{in-cone}) = +E_{\text{track}} - E_{\text{cluster}}$

NO: $\Delta E(\text{in-cone}) = +E_{\text{track}} - R_{\text{AVE}}$ \leftarrow photon-charged pion overlap

R_{AVE} = (estimate of average ECAL & HCAL response to charged hadron)

- 1) Identify whether hadron interaction started in ECAL or HCAL by checking energy in crystals.
 - 2) estimate true energy deposit in ECAL and HCAL using average longitudinal shower shape.
 - 3) estimate ECAL and HCAL response, R_{AVE} (see page 11)



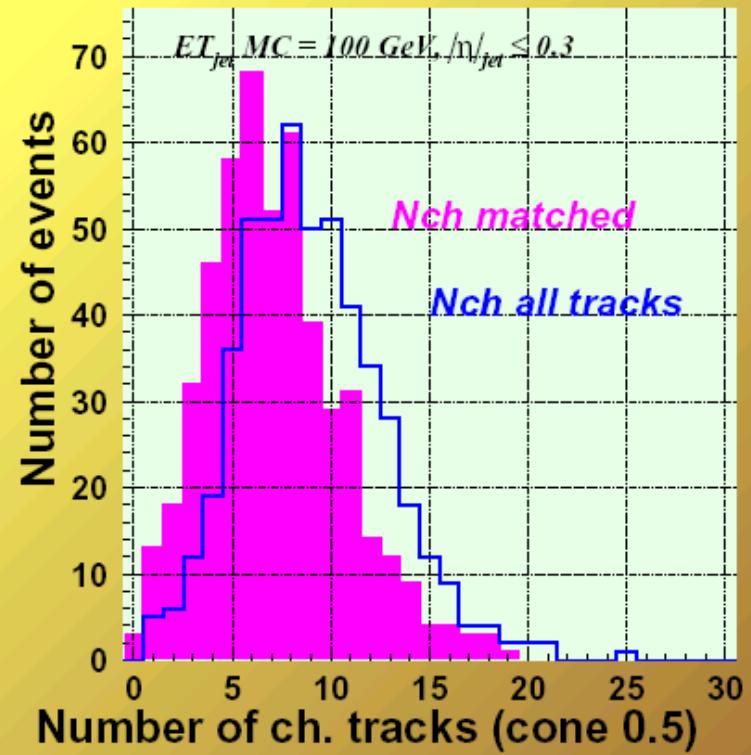
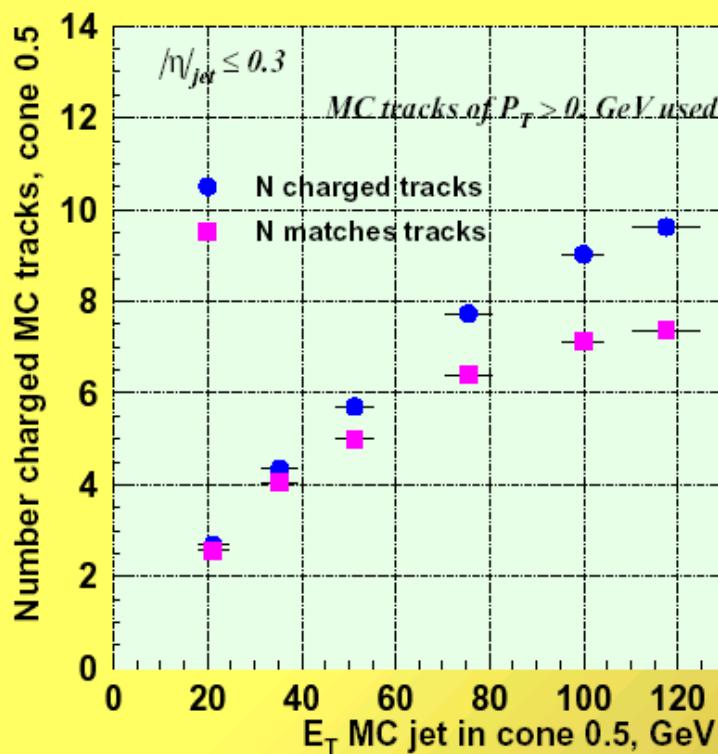
Track – Cluster Match

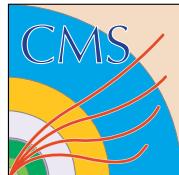
matching condition: $-\sigma < E_{\text{track}} - E_{\text{cluster}} < 2\sigma$

where

$$\sigma/E = 100/\sqrt{E} + 5\%$$

Cluster = 3x3 crystals + 3x3 HCAL tower





Estimation of Calorimeter Response

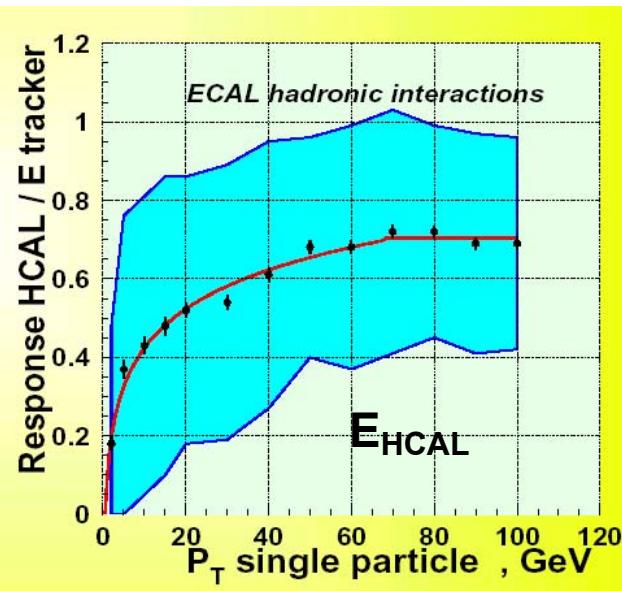
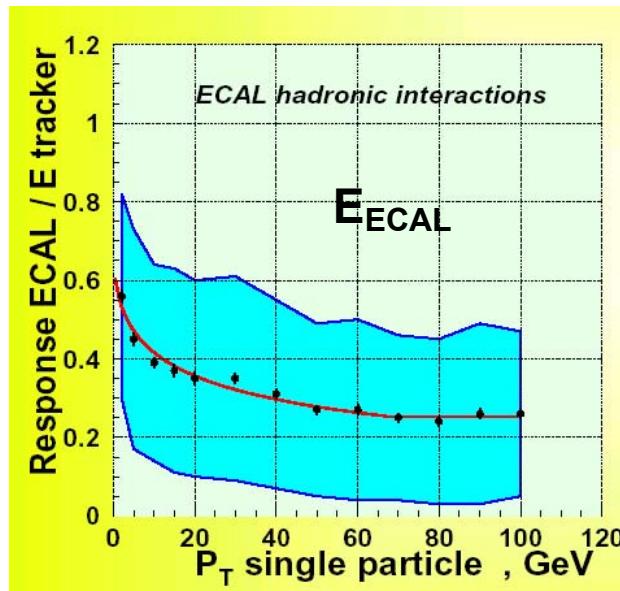
1) Simple average

	Particles interact in ECAL	Particles not interact in ECAL
R_{ECAL}	$E_{Track} * 0.4/(e/\pi)_{ECAL}$	E_{MIP}
R_{HCAL}	$E_{Track} * 0.6/(e/\pi)_{HCAL}$	$(E_{Track} - E_{MIP})/(e/\pi)_{HCAL}$

$$(e/h)_{ECAL} = 1.60, (e/h)_{HCAL} = 1.39$$

2) Library of response

GEANT3 simulation for pion interactions started in ECAL.



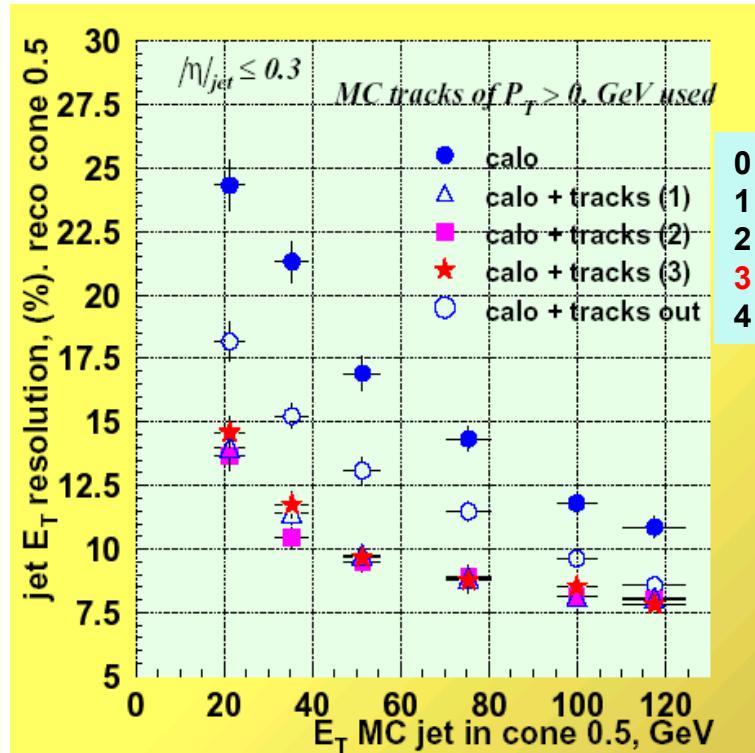


Using Tracks (#5)

Resolution & E_T Scale

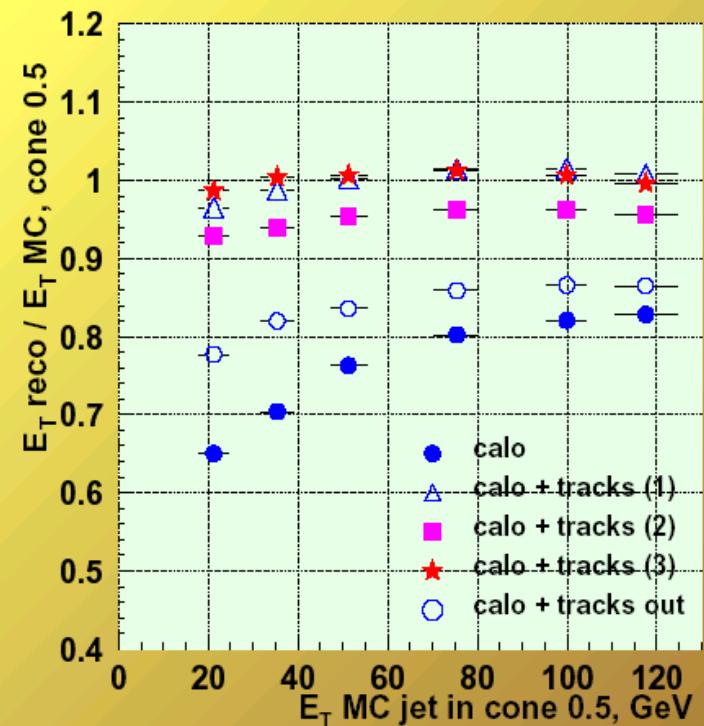
Resolution

20GeV 24% → 14%
100GeV 12% → 8%

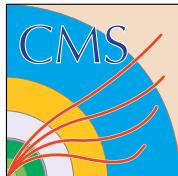


E_T Scale

$\delta < 2\%$ in 20-120GeV

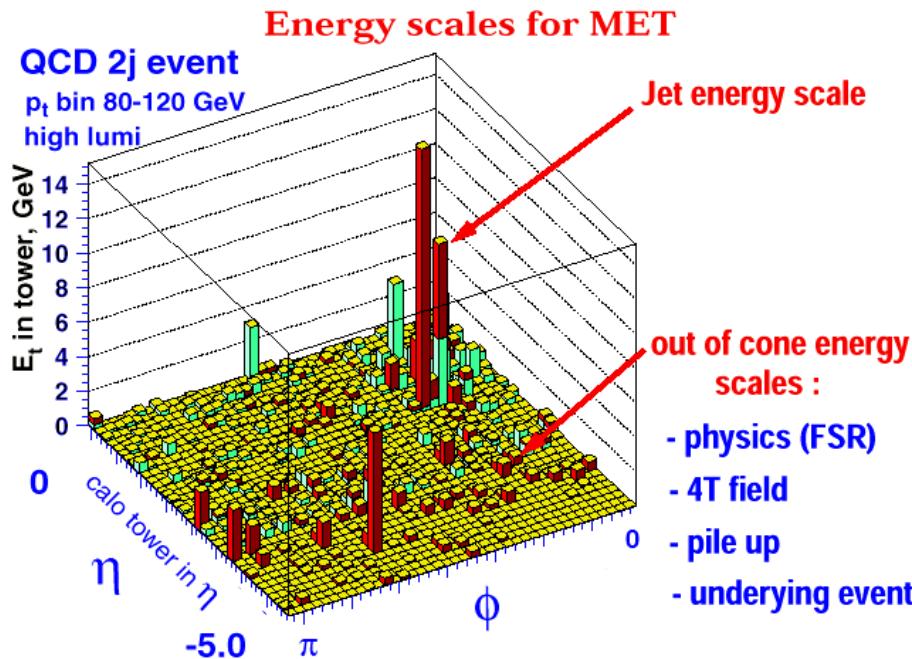


- 0: no correction (calorimeter only) 1: calo response - simple average 2: calo response – library
3: full correction (library of response, track-cluster match, out-of-cone tracks)
4 out-of-cone tracks correction only



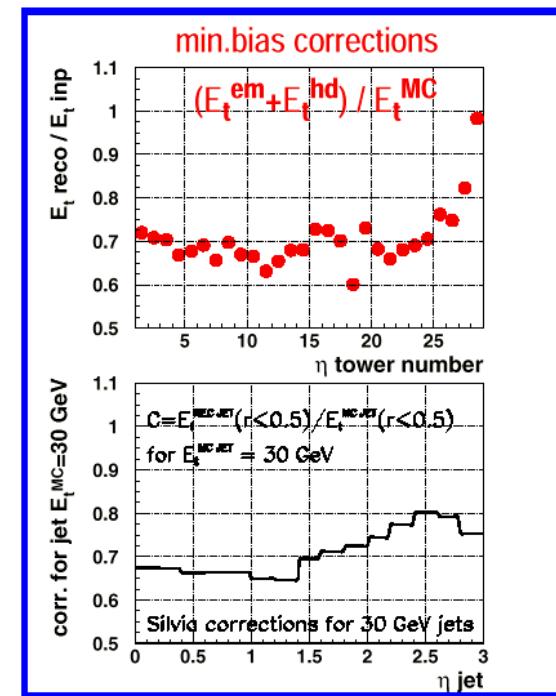
MET (Missing Transverse Energy)

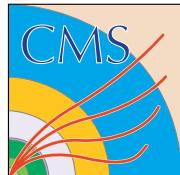
Extension of the simple jet energy correction (#1) to MET.
 $\text{MET}(\text{corr}) = \text{MET}(\text{calo}) + \sum \{\Delta E_T(\text{jet corr})_{\text{IN}}\} + \Delta E_T(\text{min-bias corr})_{\text{OUT}}$



- Corrections
- Type 1: Jet corr.
- Type 2: Jet corr. + out of cone corr.

Out of cone corr. uses weights for jet(30GeV) corr.

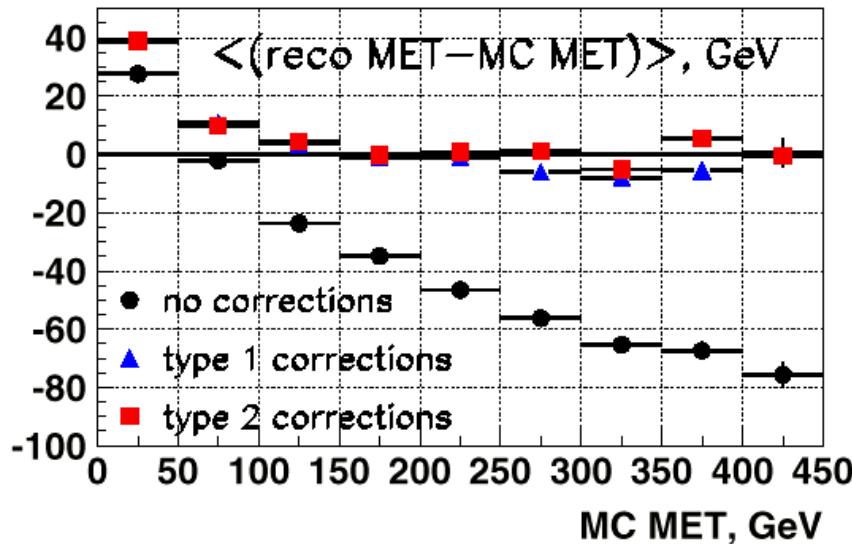




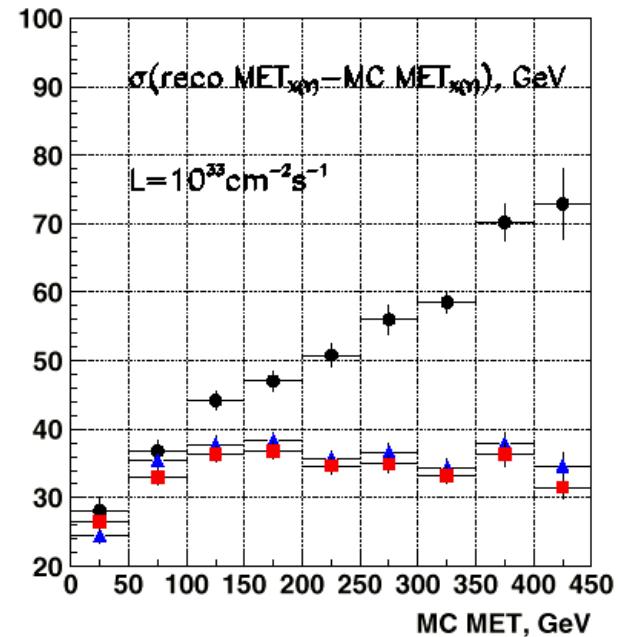
Corrected MET for SUSY

SUSY event: multi jets + MET

Mean offset

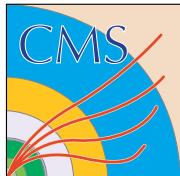


σ



An extension of the simple jet energy correction improves also MET energy scale and resolution.

Next: Extend “energy flow” algorithm to MET.



Conclusions

Various algorithms to improve jet energy scale and resolution have been tested for CMS.

- Simple mapping of jet response in η - E_T space will be used in Level 1 & HLT trigger, and offline.
- Large improvement with correction using tracks.
 - Resolution 20GeV: 24% \rightarrow 14%
 100GeV: 12% \rightarrow 8%
 - Energy scale $\delta < 2\%$ in 20-120GeV

Extensions of jet energy corrections to MET look promising.

Our next step is

- Apply those corrections to various physics processes (with complicated event structure) and test its performance.
- Do more detailed analysis and fine tuning.
- Extend “energy flow” algorithm to MET.